THE HEREDITY OF ABILITIES.

By C. SPEARMAN,

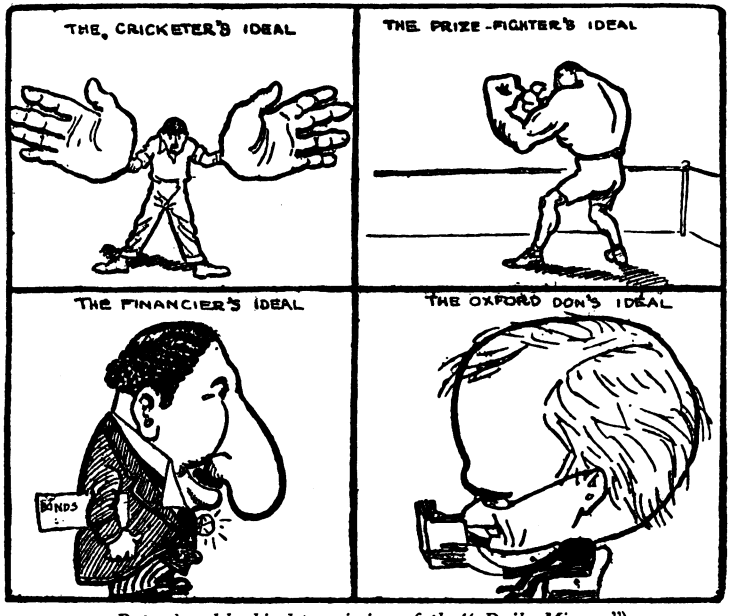
Grote Professor of Philosophy of Mind, University of London.

1.—THE PROBLEM. DIVERSITY OF VIEW.

"YOUR eugenists hope in time to produce an ideal race of men by scientific methods. But will they ever agree on the ideal to be produced?"

Such is one of the objections most frequently levelled at the eugenist movement. For instance, it has been illustrated and enforced in the daily press by the following lively sketches:—

EUGENIC IDEALS FROM DIFFERENT POINTS OF VIEW.



Reproduced by kind permission of the "Daily Mirror.")

The view underlying these sketches is, if true, damaging enough. It regards each kind of ability as conflicting with

every other kind. The progeny raised for the purposes of playing cricket would be likely to show incapacity in the matter of prize-fighting. The zygote possessing exactly the system of "gens" needed to secure academic laurels would be a disappointment on the stock exchange, and *vice versa*.

This "theory of compensation," as it has been called, is amongst the most ancient and widely accepted. It pervades literature in such mottoes as: "Ne'er a rose without a thorn." Biologists give it more definite expression in the doctrine that: "A normal or diseased organ never reaches an extraordinary size without another organ—of the same or a similar system—correspondingly suffering."[1] Or again, "When an organ from any cause has been developed excessively, then the neighbouring organs suffer thereby, they remain diminutive";[2] "when a useful change occurs at one point of the living being, at some place a change takes place in the contrary direction."[3] So too in popular psychology we find a series of beliefs such as: "that superior ability to get impressions through one sense is related to inferiority in getting impressions through other senses; that intensity of attention varies amongst individuals in opposition to breadth of attention; that the quick learner is the poor rememberer; that the man of great artistic gifts, as in music, painting, or literary creativeness, is weak in scientific ability or matter-of-fact wisdom, etc."[4]

A second view as to the relation between abilities—one whose defenders have been less numerous, but equally distinguished—is that of general independence; that is to say, it held that every ability develops without appreciable interference from the others. Among the biologists inclining in this direction is Wallace, who writes that every part or organ may exhibit large variations independently of the other parts.[5]

A similar position seems to have been defended by an important American school of psychology.[6] Even on this sup-

[1] Pr. de Saint Hilaire, Balancement Organiquement, 1807.
[2] de Caudolle, Introduction to Botany, 1835.
[3] de Caudolle, Introduction to Botany, 1862.
[4] Thorndike, Educational Psychology, 1910, p. 183.
[5] Darwinism, 1889, p. 81 ff.
[6] See Aiken, Thorndike and Hubbell, Psych. Rev., IX., 1902.

position, the eugenists would be seriously hindered. Their efforts to better the race could be of slight avail, if they had to be dissipated in hunting after innumerable independent abilities.

The third chief view—one that appears to have had, and still to have, the greatest following in psychology—is that all the varied manifestations of mental ability may eventually be traced back to a small number of basal powers, such as observation, reasoning, memory, judgment, discrimination, imagination, etc. These powers are regarded as constituting functional unities. A person gifted with close observation or sound judgment is considered able to apply such power in any direction he may choose, whether to business organization or to botanical research, to the field of battle or to the medical consulting room. But between one of these powers and another, the unity of function is no longer upheld; keen observation is not regarded as guaranteeing excellence of memory, nor is a ready memory taken to indicate profound power of judgment. This doctrine, it is clear, has much in common with the old one of "faculties"; it differs therefrom in having dropped all the latter's metaphysical implications; but it still retains similar functional unities. Here, the task of eugenics would at any rate be reduced to reasonable dimensions; instead of innumerable independent abilities, there would only be some half a dozen basal powers to cultivate.

But far more hopeful still is the fourth view, voiced by Carlyle: "For at bottom the great man, as he comes from the hand of nature, is ever the same kind of thing: Odin, Luther, Johnson, Burns; I hope to make it appear that these are all originally of one stuff; that only by the world's reception of them, and the shapes they assume, are they so immeasurably diverse."[1] Similarly, if in more prosaic fashion, among many psychologists "the assumption seems to have been that intelligence is some central ability which comes into function in every mental operation, and that if a person has a certain degree of intelligence in one direction, and if allowance is made for practice, experience, and acquired interest, he will be found to have about the same degree of intelligence in other

[1] Heroes, Hero-worship, and the Heroic in History, Lect. II.

directions."[1] Indeed, it is in this view, it would seem, that the logical basis must be found for many of our social institutions. It is hard to see else, for example, why we should examine our young men in Latin and Greek in order to select the fittest for ruling the inhabitants of India.

How shall we decide between these four, and possibly other, claimants upon our belief and action? Each of them quotes weighty authorities on its side; each is the product of a wide range of actual experience; each is affirmed with the same confidence—not to say, intolerance of contradiction. Ordinary experience and knowledge of human nature have, then, foundered into a quagmire, from which they appear impotent to extricate themselves.

2.—Modern Methods of Investigation.

Fortunately, there has in recent years sprung up a psychology of more exact character. For the purpose of estimating abilities, we are no longer at the mercy of hearsay, casual experience, and remote reminiscence; instead, the abilities can be definitely measured and permanently recorded. Further, there is no longer any need to trust in general impressions on the all-important point, as to whether two series of measurements are dependent on one another. Through the genius of Galton, we can now estimate the degree of correspondence between the two series by means of the "correlational coefficient."

This is so constructed that, when the two series are strictly proportional to one another, it takes its maximum value of +1. Such should be its amount between the measurements of the same set of persons in two different kinds of ability, then, if Carlyle is right in holding different abilities to be essentially the same.

As the correspondence between the two series becomes less and less close, the coefficient continually diminishes; and on their being wholly independent of one another, it goes down to 0. This, then, is the result needed between different kinds of ability, in order to agree with the independence theory.

[1] Colin Scott, Jour. Ed. Psych., IV., 1913, p. 509.

When the measurements in the one series even tend in the reverse direction to that of the other series, the coefficient takes a minus value, with an extreme limit of -1. Some such minus value can alone satisfy the theory of compensation.

Finally, for agreement with the view of basal powers or "faculties," the coefficient should vary according as any two abilities compared with one another belong to the same or to different powers. In the former case, it should approach to $+1$; in the latter to 0.

These newer methods have been freely put into practice. A great variety of test performances, including many kinds of observation, memory, reasoning, etc., have been devised and applied to thousands of men, women, and children, in every civilized country. The surprising result has been, however, not a verification of one theory out of the four competitors, but a refutation of them all. Nothing could be more emphatic than the rejection of the theory of compensation championed by the newspapers; the correlation between different abilities has turned out to be never inverse, but always direct; the fear of one mental endowment being at the expense of another has been allayed. The theory of independence is also put out of court, since the correlation has rarely been zero. But on the other hand, it has not risen to $+1$; nor does it seem capable of doing so with any equalization of experience and interest, as needed to agree with Carlyle. Still less has it alternated between plus one and zero, as demanded by the theory of faculties.

3.—The Law of Proportionality.

This unsatisfactory result is a useful warning against the earlier extreme notions about the use of correlational coefficients. Some of their advocates seem to have naively hoped that the bare calculation of the coefficient would furnish the last word of science. Everywhere this expectation has been disappointed. Scientific investigation has proved itself to require, over and above mathematics, a profound knowledge of the concrete facts, together with an active experimental groping after new points of view. But still less support has been given to the opposite extreme view,

which desired to continue placidly in the old rut of investigation, regardless of the new potent calculus offered to them. The complexity of science, far from dispensing with mathematics, only makes the higher claims on their services; if rejected in their original crude forms, they sooner or later return to the field in greater elaboration than before. In the present case, we shall find that the problem which was so insoluble by single correlational coefficients yields easily enough to the consideration of systems of correlations.

This may be illustrated by an instructive research due to Bonser.[1] He applied five intellectual tests to 757 schoolchildren, and calculated the correlational coefficients by the usual method (that of "product moments"). The results are given in the following table.

TABLE I.

Bonser's Correlations.

	Selective judgment.	Mathematical judgment.	Spelling.	Controlled association.	Literary interpretation.
Selective judgment		·397	·195	·397	·335
Mathematical judgment	·397		·295	·485	·400
Spelling	·195	·295		·247	·275
Controlled association	·397	·485	·247		·397
Literary interpretation	·335	·400	·275	·397	

At first glance, the figures look as unpromising as before; not one of them suits any of the four theories mentioned above. But let us turn from the single values to the table as a whole, and consider, not the absolute, but the relative magnitudes. Take any two colums, for example, the first and second, omitting the values that have no correspondent in the other column. This gives Table II.

TABLE II.

The first two columns from Table I. :—

1	2
·195	·295
·397	·485
·335	·400

[1] See Brit. J. Psych., V., 1912, p. 62.

It is at once seen that the values in column one are very nearly proportional to those in column two. But the tendency of two series of values to be proportional to one another is just what is measured by correlational coefficients. Let us, then, measure the correlation between column one and column two. This correlation between columns of correlations, calculated in the usual way, turns out to be no less than plus 1·00; that is to say, it is perfect to the first two decimal places.

The procedure which we have just applied to columns one and two is, of course, equally applicable to any other pair of columns. In all, there are ten different pairs. Out of these, the correlation between correlations comes no less than four times to the complete plus unity. Once, it comes to +·99; once, to +·98; while even the remaining four pairs give high positive values.

Such a constant and close adherence to proportionality is beyond all suspicion of arising from mere chance. It becomes necessary, then, to inquire under what conditions it occurs. This is a question requiring careful reply. Though the phenomenon is palpable enough in the above instance when pointed out, it may otherwise easily escape detection; Bonser himself seems to have quite overlooked it. But in other similar investigations, even keen scrutiny will rarely find cases so evident as to be beyond the range of dispute.

It must, however, be remembered that in psychology, as in physics and other sciences, the raw experimental data are subject to various disturbances, for which due correction must be made. A mechanical machine always appears at first sight to give out less energy than is put into it, a fact which, if verified, would contradict the law of conservation. But narrower inspection invariably shows that there has been an escape in other forms, such as heat, On making the necessary corrections, the energy put into the machine and that taken out of it always prove to be equal. Analogous corrections are naturally required in the case of our tables of correlations also; generally, they will be of a very simple character, consisting merely in an allowance for the "errors of sampling" (*i.e.*, the

errors whose general magnitude is indicated by the "probable error" of the coefficient).

TABLE III.

Correlation between correlations for all hitherto published researches.

Year.	Investigator.	Subjects.	Mean Correlation between Correlations.
1889	Oehrn	10 students	> + ·93
1902	Thorndike	160 boys and girls	+1·04
1904	Spearman	37 boys and girls	+1·16
1904	Spearman	24 boys and girls	+1·01
1906	Krueger and Spearman	11 students	> + ·96
1908	Peterson	96 students	> + ·94
1909	Foerster and Gregor	11 insane patients	+1·12
1909	Burt	30 boys	+1·06
1909	Burt	13 boys	+1·06
1910	Brown	56 boys	+ ·86
1910	Brown	39 girls	+1·02
1910	Brown	40 boys	+ ·97
1910	Brown	23 students	+ ·93
1910	Brown	56 women	+ ·89
1910	Bonser	385 boys	> + ·97
1910	Bonser	372 girls	> + ·96
1912*	Simpson	37 adults	+ ·96
1913*	Wyatt	75 children	+ ·97
1914*	Abelson	78 children	+1·02
1914*	Webb	200 students	+1·02
	Average	... ...	+ ·99 ± ·01

The above data up to Bonser inclusive are given with detailed references and a discussion of the whole problem in a paper on "General Ability" by Hart and Spearman, Brit. J. Psych., V., 1912, p. 51. The data for Simpson are given in "The theory of two factors" by Spearman, Psych. Rev., March, 1914. Those of Wyatt appeared in his paper in the Brit. J. Psych., VI., 1913, p. 109. The researches of Abelson and Webb are just about to be published. It should be noted that the method of "correction," as usual, is devised so as to furnish a value which will be right *on an average*. Consequently, when, as here, the true value approximates to complete unity, about half of the individual 'corrected" values ought to be greater than unity; although, of course, no true value of a correlational coefficient could be greater.

On making such corrections, the remarkable and apparently exceptional proportionality found in the above table of Bonser proves to hold good *universally and exactly*. Facing is a table summarizing the work of all the investigators of the subject, most of whom approached the problem with a strong bias against the proportionality and its theoretical consequences; even in publishing their results, they declared the proportionality to be absent.[1] But at that time, the methods of calculation were comparatively crude. On applying the present more exact methods, the following list of results ensues. The average value of the correlation between correlations comes to + ·99 + ·01; and in not one single case is the departure from + 1 greater than could reasonably be attributed to mere chance variation of samples. It is not too much to say that such an agreement between all investigators at all times and under all conditions is unparalleled in psychology and scarcely to be matched in the most exact of the sciences.

4.—The Theory of Two Factors.

We have thus succeeded in piercing the outward shell of seeming irregularity in the experimental results, and have penetrated to an underlying universal orderliness. The next step is to ascertain what light is thereby thrown on our present problem, the connection between different abilities.

It may easily be shown that we are as far as ever from being able to accept any of the four previously mentioned rival solutions. Just as these could not be reconciled with the absolute values of the correlations between abilities, so too they are incompatible with the proportionality between these correlations.[2]

It has turned out, however, that, though every one of the four views taken singly is impotent to explain the facts, a perfect solution is afforded by two of them taken in combination. These are the second and fourth, the former holding that all the abilities are independent of one another, and the latter that they are all connected by common dependence on the same thing. That is to say, the sole hypothesis compatible with the

[1] Those who, on the contrary, have supported the proportionality are Krueger, Burt, Wyatt, Abelson and Webb.

[2] For proof see "General Ability," Brit. J. Psych., V., 1912.

facts is that every ability depends on *two* factors; the one of these is a specific ability or disposition, different and independent for every different kind of ability; the other is the general energy of the mind, always the same. The mathematical proof of this fundamental proposition of psychology is so simple that it can be given below in a footnote.[1]

This analysis of every mental ability into two factors will be found by many to be more clearly conceivable when expressed in terms of physiology. The function of the central nervous system has for centuries been the subject of heated controversy. On the one hand, Flourens and his followers have declared that the whole cerebrum acts as one single organ subserving any kind of mental operation. On the other hand, a long array of investigators have maintained the directly opposite doctrine, that every part and parcel of the cerebrum has its special work to perform. The above discovery of the two factors supplies the simple reconciliation between the two warring parties; as so often occurs, both were right in what they affirmed, but wrong in what they denied. Every mental process is, indeed, served specially by some particular part or process of the cerebrum; this constitutes our specific factor, different and independent for every different ability. But at the same time, every mental process utilises also the energy of the whole cerebrum, especially the cortex; this is the general factor, always the same whatever the mental process.

The double truth had already been suspected by some of our leading physiologists and neurologists. Mott, for instance,

[1] Let a, b, p, and q denote any four abilities, each assumed to depend partly on a specific independent factor, and partly on a general factor; call the latter G. Let the correlations between the abilities be written in the usual way as r_{ab}, r_{aq}, etc. As the specific factors are by assumption independent of one another, any correlation between the two abilities must be due to the G and would vanish if the influence of G were eliminated. But Yule's well known formula for partial correlations expresses the value of a correlation on elimination of a factor (Introduction to the Theory of Statistics, p. 235). By this formula, the correlation between a and p on excluding G is:

$$\frac{r_{ap} - r_{aG} \cdot r_{pG}}{\sqrt{1 - r_{aG}^2}\sqrt{1 - r_{pG}^2}}$$

And as this value vanishes, $r_{aG} \cdot r_{pG} = r_{ap}$; similarly, $r_{bG} \cdot r_{pG} = r_{bp}$. Hence, $r_{aG}/r_{bG} = r_{ap}/r_{bp} =$, in the same way, r_{aq}/r_{bq}. So that $r_{ap}/r_{bp} = r_{aq}/r_{bq}$, which is precisely the proportionality actually observed, making the correlation between the columns = plus unity.

twelve years ago suggested in this sense that "the total nervous energy is at the disposal of the whole nervous system"; and the suggestion elicited the cordial approval of Sherrington (Journal of Mental Science, 1902, Oct.). Further, the psycho-physiological work of McDougall, if not as yet reaching quite to our present problem, appears to be directly heading towards the above analysis into the two factors.

5.—Mental Measurement.

Thus, then, the eugenic problem from which we set out has reached a definite solution in the theory of "two factors." And here eugenics will find, it is believed, not only a refutation of popular objections, but also a general firm basis for positive investigation. In particular, this theory appears to make possible, for the first time, meaningful and reliable *mental measurement,* a matter in which previous researches have been gravely defective.

The prime necessity is to distinguish mental measurements into three classes. Of these, the first is that directly obtained from any properly conducted test; it indicates the person's total power for that particular kind of performance. The other two classes of measurement are only to be got by theoretical deduction from the first class; they refer to the two factors, general and specific.

We will consider the general factor first. Perhaps the nearest approach to it previously has been the "general intelligence," as estimated by school teachers, fellow pupils, medical attendants, prison warders, etc. Unfortunately, investigation has shown such estimation to be vitiated by errors of surprising magnitude. This erroneousness is now usually measured by means of the "reliability coefficient," or correlation between two independent estimates of the same thing; evidently, this must approach to plus unity, as the estimates become perfectly correct. When the present writer first reported the reliability coefficients for estimation of general intelligence to be as low as ·64, he was suspected of exaggeration. But further inquiry has proved matters to be, if anything, worse. An extensive research has just been completed in our laboratory by Mr. Webb. Two

hundred students in a training college had their principal qualities estimated by their prefects; these were fellow students, with whom they were in continual contact. To each prefect were allotted twenty students, to be carefully observed for six months. The average reliability coefficient proved to be as low as ·55.[1] Even less successful have been the estimates made in schools. Recently, the general intelligence of 1,405 children was judged, in each case by two teachers independently; the correlation between the two judgments came to no more than ·47. In a second investigation involving 2,018 children, the correlation came to ·50. Even more significant is the fact that when, in a further investigation, the two estimates of the same child were made by one and the same teacher, but with a lapse of nine months between them, the correlation still only came to ·66. Moreover, the investigator, Waite, convinced himself that substantially the whole of this astonishing discrepancy lay with the teachers' judgments, and not with any real changes in the children.[2] The effect of such errors of measurement is to reduce or "attenuate" the correlation by an amount admitting of precise valuation.[3] This amount is sufficient to render the correlations usually published invalid and delusory.

Nor is this all. It must be remembered that the reliability coefficient only manifests those errors which vary from one estimator to another; they say nothing about any bias common to both. This has turned out to be, at times, even more extraordinary. In Mr. Webb's research, for example, the prefect's estimates of the "quickness of intelligence" of their fellow students proved to be almost wholly based on the latter's manifestations of humour; the correlation between the estimates of intelligence and those of humour was no less than ·85. Naturally enough, the humour showed no appreciable correlation with the intelligence of the students when measured in any other way, whether by the estimates which the teachers made, or by various objective tests; humour is generally recognised to depend rather

[1] Proceedings of Brit. Psych. Soc., 24-1-1914.

[2] Biometrika, VIII., 1911.

[3] Amer. J. Psych., XV. 1904, p. 289; Brit J. Psych., III., 1910, p. 271; Ibid., V, 1913, p. 417. The formula usually most convenient is that given at the top of p. 276, Vol. III., Brit. J. Psych.

on emotional than intellectual factors. Similar estimates by other judges appear to be little better off; some have one kind of bias, others another. If the teachers escape the bias towards humour, they fall into that towards examinational success.

A very different picture is presented by diagnosis based on the experimental determination of our general factor, the free energy of the cortex. This admits, not only in principle, but to a large extent in practice, of as definite measurement as the length of an arm or the circumference of a head. Also the probable error of the measurement can be determined at the same time. The simple formula combining both purposes is:—

$$G_x = T_x \cdot r_{TG} \pm .67 \sqrt{1 - r_{TG}^2} \qquad (1)$$

where T_x denotes the result of the experimental test T applied to the person x, G_x is this person's general mental energy, and r_{TG} is the correlation between the test and the general energy.

The formula (1) is directly derivable from the theory of correlations.[1] The essential point is that, recently, a method has been devised for determining r_{TG}, thereby rendering the formula usable for our present purpose.[2]

It is clear that the error of G_x diminishes as r_{TG} increases. Also, it has been shown that the size of r_{TG} is enhanced by letting T consist, not of a single test, but of many tests pooled together.[3]

So far we have regarded only the general factor in ability and the inadequate surrogate for it presented by the popular "general intelligence." But analogous considerations apply to the specific factor also. Here, the popular surrogate is even less adequate; a person's specific ability for a performance is confused with his total power for it, although the two may in reality vary inversely. Suppose, for instance, that a child surpasses most of his fellows in the power of remembering colours; this would usually be taken as indicating a specific ability for this operation. But the child might possibly manifest an even greater superiority at most other intellectual

[1] Yule's Introduction to the Theory of Statistics, pp. 177.

[2] See Mental Tests of Dementia, Hart and Spearman, to appear in the next number of the Journal of Abnormal Psychology.

[3] See Abelson, Brit. J. Psych., IV., 1911, p. 298; also "The Correlations of Sums" in the same journal, Vol. V., 1913, p. 417.

operations; his power of remembering colours, though good as compared with that of his comrades, might nevertheless be poor as compared with his own general ability. Physiologically expressed, the particular cortical structure subserving the operation might in itself be weak, but be rendered efficacious by the extremely high grade of the supporting energy of the whole cortex.

To determine the specific ability, then, we have first to deduct the influence of the general ability. This gives, as a first approximation, and on choosing suitable units:—

$$t'_x = t_x - G_x \qquad (2)$$

where t_x denotes the total power of the person x for the test t, G_x is his general ability, and t'_x is his *specific* ability for the test. t and t′ will, of course, usually refer to some single test, not to a pool of them as the T in equation (1).

6.—Determination of the Influence of the Environment.

Having achieved this indispensable preliminary of measuring the two factors in ability, the next task is to ascertain how far they are respectively transmissible by inheritance. The direct method of attack is a comparison between the qualities of the parents and those of the offspring. But the difficulty of effecting this in the case of the human race has led to the adoption of a less direct procedure; the attempt is made instead to determine in the first place the influence of the environment; and then, all variation not traceable to the environmental influences is attributed to heredity.

If we may believe the statements made in newspapers and public speeches by many eminent politicians, divines, sociologists, and others, the influence of the environment on general ability may be very great. Nor have educationalists been behindhand; there is not one of the ordinary studies, whether classics, mathematics, science, or modern languages, that has not been recommended for its peculiar efficacy in promoting the growth of "general intelligence." Similar claims are being put forward on behalf of manual training. During the last few months we have even been gravely assured that a general intellectual expansion may be secured by well devised dancing exercises.

Eugenic research, however, appears to have uniformly arrived at negative results; it has always reported the action of the environment to be insignificant. And this conclusion has been corroborated by the more exact work in psychological laboratories. For instance, the investigations into the so-called "formal training" have decisively contradicted the claims of particular studies to produce improvement of a general character; whenever any kind of performance has been trained, that kind—with all its constituent elements—has alone reaped the benefit.[1]

This seems to indicate that the effect of training is confined to the specific factor and does not touch the general one; physiologically speaking, certain neurons become habituated to particular kinds of action, but the free energy of the brain remains unaffected.

Further corroboration may be found in the evidence as to the time at which this general cerebral energy becomes mature. This, as far as can be seen at present, is surprisingly early; the cerebral energy seems to be nearly complete by the age of puberty. The experimental determination is far from easy, and almost all the results hitherto published are vitiated by such grave errors as to be quite untrustworthy. But, perhaps, the least affected is the above-mentioned work of Bonser, and his results in this respect are given in the following table.

TABLE IV.

The percentage of children reaching each of the five grades of ability at Bonser's tests.[2]

Grade of ability.	Years of Age.					
	8–10	10–11	11–12	12–13	13–14	14–16
I.	5	4	2	2	4	2
II.	17	9	10	8	15	10
III.	31	30	27	26	21	30
IV.	37	35	35	39	39	33
V.	10	22	26	25	21	25
	100	100	100	100	100	100

[1] See especially the elaborate research conducted (in our laboratory) by Dr. Sleight, Brit. J. Psych., IV., 1911.

[2] See his "Reasoning Ability of Children," Columbia University Contributions to Education, 1910, p. 75.

It is clear that the children under 10 years of age furnish a relatively small percentage in the highest grade of ability; but afterwards, if these rather surprising values may be trusted, the improvement with age is so minute as to be masked by the variations due to mere chance.

That general mental ability reaches its full development about the period of puberty is still further evidenced by physiology. For the human brain has been shown to attain its maximum weight between the ages of 10 and 15 years.[1] And since the general ability is so little affected by all the years of education after puberty, it can have but little dependence on education at all.

If this reasoning is accepted, we arrive at a conclusion of fundamental importance for eugenics. This is that, though unquestionably the development of specific abilities is in large measure dependent upon environmental influences, that of general ability is almost wholly governed by heredity.

There is, however, at present, a weak point in the above reasoning and in the whole attempt to estimate the influence of heredity through that of environment. It involves some common but questionable assumptions. In particular, the "environment" is taken in the sense of the ordinary outer world, where the sun shines and the air circulates. But does not really the environment begin where the gametes first unite into a zygote, or even earlier? If one may judge by analogy with the lower organisms, some such extremely early stages of existence engender very large non-inheritable differences between individuals. A notable example has been found in the culture of beans. When continued careful selection has secured a perfectly "pure" variety of this plant, the offspring still continues to differ largely both from the parents and from one another; some, for instance, will be much heavier and others lighter. But if the heaviest be sorted into one group and the lightest into another and both groups be further bred from, the offspring of neither group will show any advantage as to weight; nor will such differentiation appear even if the selection be continued for several generations.[2] If this is experimentally

[1] See Vierordt, Arch. f. Anat. und Physiol., 1890.
[2] Johannsen, Elemente d. exakten Erblichkeitslehre, 1914, ch. IX. and X.

demonstrable in the case of plants, there is surely no warrant for taking it to be *a priori* impossible in the case of man. It still, therefore, remains conceivable, that individual differences of general ability, though not due to environment after birth, may nevertheless be largely due to environmental influences at an earlier period, of whose conditions we have not yet any definite knowledge.

7.—DIRECT DETERMINATION OF THE INFLUENCE OF HEREDITY.

Here, therefore, the investigation of heredity through that environment breaks down. At any rate, it requires to be supplemented by other more direct procedures.

The most prominent of these, at present, is the determination of correlations between brothers or sisters. And although the earlier researches on these lines had to suffer from the difficulties that almost inevitably beset pioneering work (especially the above-mentioned "attenuation" of correlation by errors of measurement), such disturbances may well be overcome in the future. Nor is the old objection insuperable, that any observed resemblances between the brothers and sisters may be due, not to common ancestry, but to common home education, etc. This would only be fatal to the procedure as a self-sufficient mode of investigating heredity, not as a supplement to the investigation of the environmental effects.

But there still remains the difficulty arising from the above-mentioned prenatal influences. The result of these must be an undue lowering of the correlations observed between brothers and sisters. The observed values of the correlations can perfectly well furnish proof that qualities are inherited, but it is hard to see how they can ever measure the full amount of this inheritance.

Thus, there seems to be no escape from facing the problem of heredity in the most direct manner, by determining the correlations between parents and offspring. Nor does the task—in view of the psychological discoveries given in the earlier part of this paper—any longer present insuperable obstacles. Definite measurements of both specific and general ability can be made on parents and offspring alike.

The specific abilities might seem to present little interest. Our knowledge of a person's intellectual capacity is not, it might be thought, very usefully advanced by measuring exactly how well he can memorise nonsense syllables or erase the r's in a page of print. But it must be remembered that in some cases, as in word blindness, a specific inability may have very widespread and serious consequences, even for practical purposes. While for the theoretical investigation of the laws of heredity, specific abilities are likely to prove as fundamentally important as general ability itself, and they are certainly far easier to determine.[1]

One often expressed fear must here be dismissed briefly. It has been said that the abilities of parents and offspring do not admit of comparison owing to the large differences of age between the two. This difficulty is to some extent eliminated by the above-mentioned fact, that general ability ripens so early. But in any case, each class can be measured according to its own appropriate standards. The feasibility of this has been demonstrated by the relatively successful standardisation of the Binet-Simon tests, although these are probably as far behind future tests as Fitch's steamboats were inferior to modern Atlantic liners.

8.—HEREDITY DEDUCED FROM THE THEORY OF TWO FACTORS.

There is yet another method of arriving at evidence concerning the inheritance of general ability. We have seen that the correlations between mental tests present such numerical relations as to be solely explicable by some general factor in all the abilities tested. The psychologists who demonstrated this fact refrained from proceeding to draw any conclusions as to how far this general factor could be considered innate. The merit of bringing forward this point belongs to Dr. W. Brown, who made the important observation that a general factor might possibly be produced by conditions of environment. He suggests the conceivability, for instance, that some of the children tested might have had a stricter discipline than the others, and

[1] It has been shown, especially by Burt, that general ability is most strongly manifested by tests involving the higher mental processes, such as reasoning, etc. And these tests present some experimental inconveniences.

thereby have gained an advantage which would serve them more or less in all the tests; that is to say, the superior discipline would furnish a general factor, exactly as indicated by the correlations.[1]

Now, this idea admits of interesting developments. No one, it seems safe to assume, will think of attributing the *whole*, but only a part, of the observed correlations to such casual influences. Let us accordingly suppose that the different degrees of success at the tests are partly due to innate differences of capacity and partly to acquired differences of discipline. Each of these two kinds of influence will, naturally, have its sphere of special effectiveness. Thus, while the innate capacity might mainly make for success in tests of a highly intellectual nature, the benefits of superior discipline would be most evident in unremitting application to tests that were long and dull. But it has been demonstrated that in the case of two or more such diversely acting influences, the correlation between correlations, far from amounting to the plus unity actually found, would necessarily have a very low or even minus value.[2]

The conclusion seems inevitable, that the general ability indicated by Table III. does not appreciably depend, either upon discipline, or upon any other analogous influence of the environment.

To sum up, it appears that the future of research into the inheritance of ability must centre on the theory of "two factors." This alone seems capable of reducing the bewildering chaos of facts to a perspicuous orderliness. By its means, the problems are rendered clear; in many respects, their answers are already foreshadowed; and everywhere, they are rendered susceptible of eventual decisive solution.

[1] Brit. J. Psych., VI., 1913, p. 235.

[2] Such diverse influences would produce what has been called the "multifocal" type of correlational tables, see Brit. J. Psych., V., 1912, p. 57.